An assessment of basal melt parameterisations for Antarctic ice shelves

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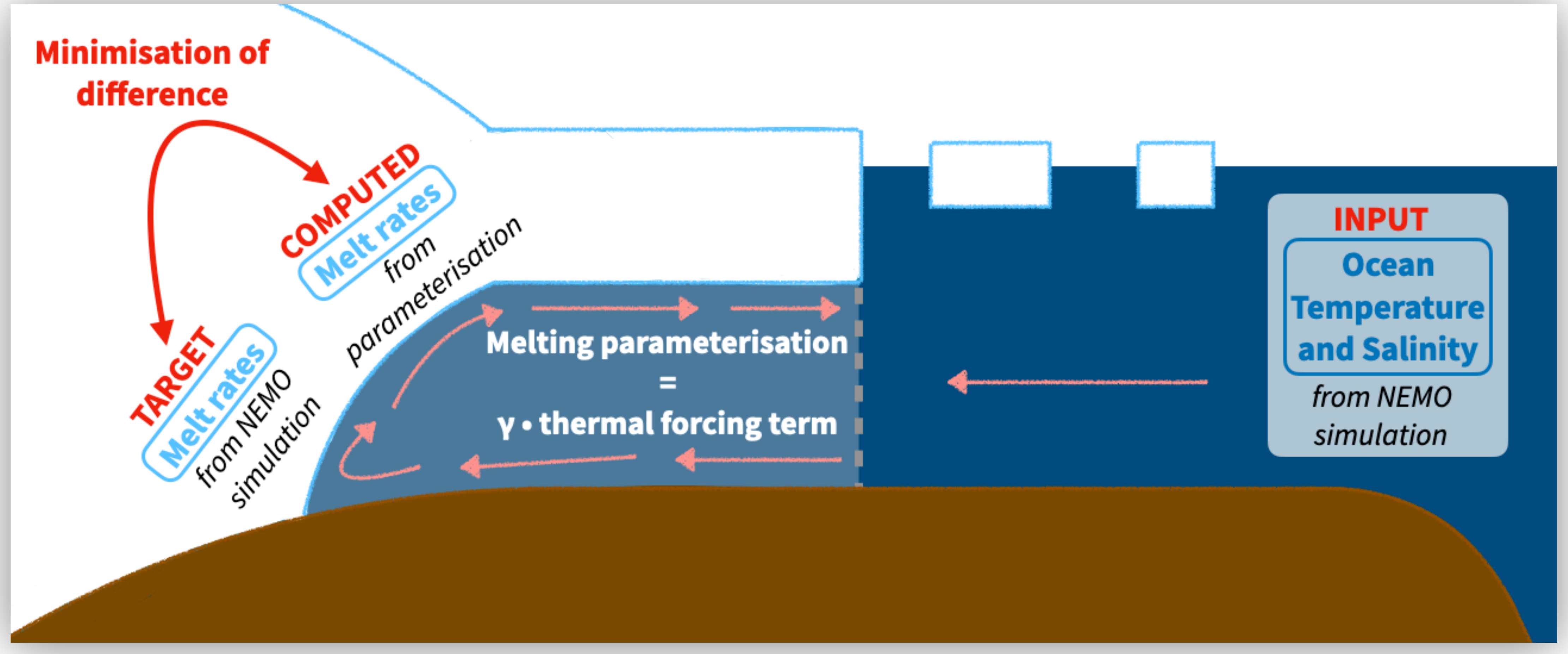
This work is part of
Protect
CRYOSPHERE & SEA LEVEL

What you should take home…

Melt parameterisations bridge the gap between open ocean properties and the ice shelf base in uncoupled ice sheet models

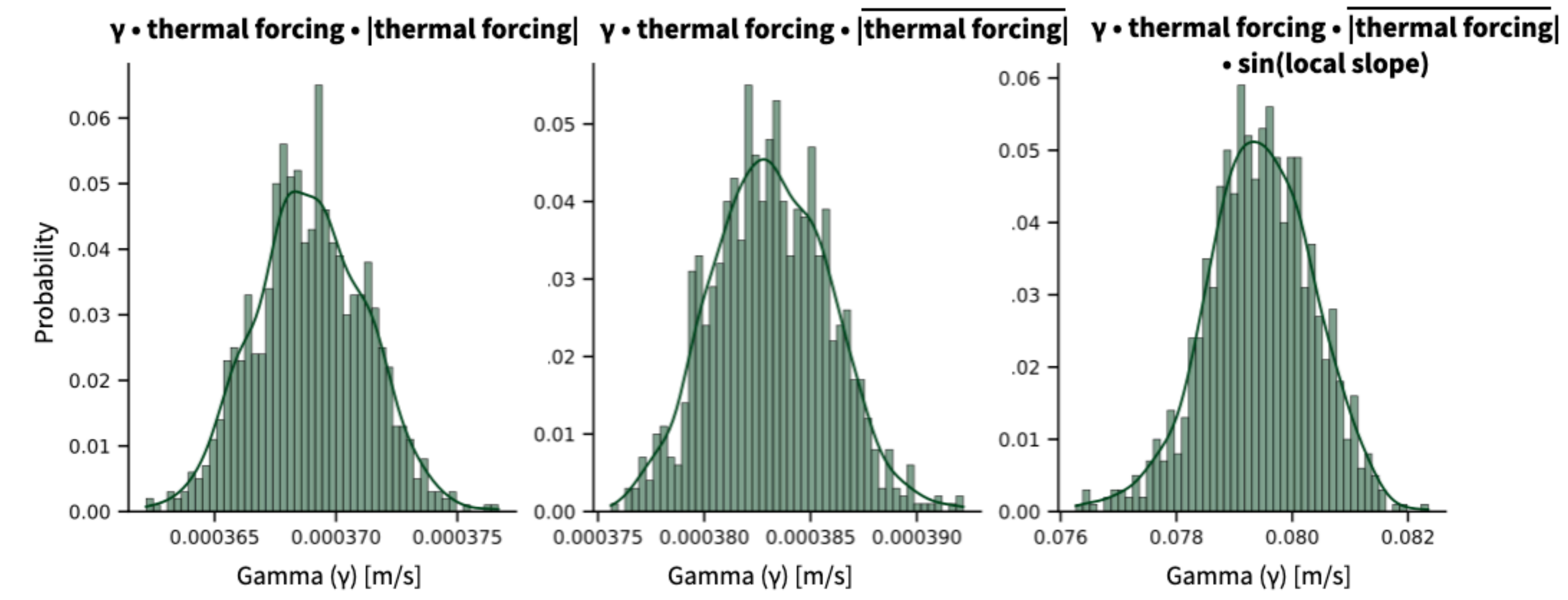
Currently, **individual corrections are needed** for each ice shelf when simple melting parameterisations are used. Here, we take a **circum-Antarctic** approach.



We use a **"perfect-model" approach** with a circum-Antarctic ocean simulation to **tune the simple parameterisations** using the 36 resolved ice shelves in the simulation over 38 years.

We **infer values of γ** using a linear fit and **investigate the uncertainty of the inferred values of γ** using bootstrapping.

The **median values of γ are close to the ISMIP MeanAnt** recommendation but the **uncertainty around the median values is much smaller** than the window between the MeanAnt and PIGL recommendations.



ISMIP values *(from Lipscomb et al. 2021 and Jourdain et al., 2020) [in m/s]*

MeanAnt	3.51×10^{-4}	4.56×10^{-4}	6.53×10^{-2}
PIGL	1.57×10^{-3}	5.04×10^{-3}	1.70×10^{-1}

***Our** results [in m/s]*

5th pctl	3.65×10^{-4}	3.79×10^{-4}	7.78×10^{-2}
Median	3.69×10^{-4}	3.83×10^{-4}	7.95×10^{-2}
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Coming soon: *similar tuning approach for complex parameterisations!*

1 The problem

Representing ocean basal melting in (uncoupled) ice sheet models

2 Our goal

Improve ocean basal melt parameterisations for ice sheet models

3 What has happened before…

4 How we tackle the problem

5 First results: Tuning the simple parameterisations in a circum-Antarctic approach

6 Coming soon: Tuning the complex parameterisations in a circum-Antarctic approach

The problem: Representing ocean basal melting in (uncoupled) ice sheet models

Ice sheet models need information about the ocean water interacting with the ice at the lower boundary of the ice shelves…

However: Sub-shelf cavities are typically not resolved in ocean or coupled-climate models…

The link between the open ocean and the ocean-ice sheet interface is missing!

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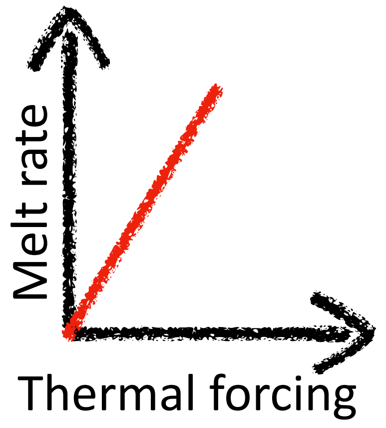
Our goal: Improve ocean basal melting parameterisations for ice sheet models

We assess and tune existing sub-shelf melt parameterisations in a circum-Antarctic approach.

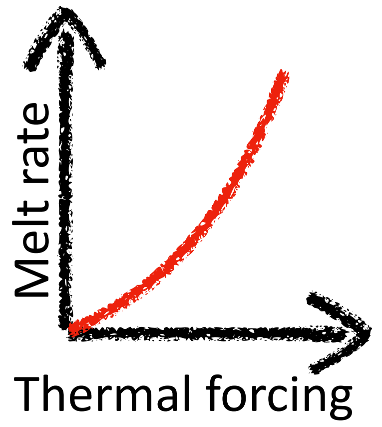
What has happened before…

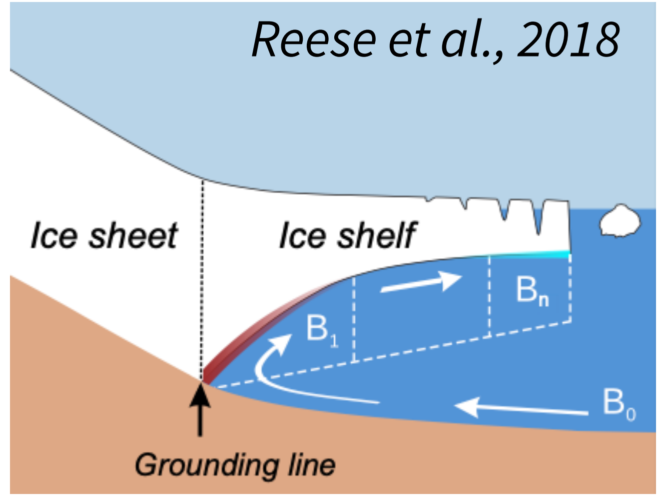
The evaluation of existing parameterisations is challenging.



Linear function of thermal forcing
[Beckmann & Goosse (2002)]

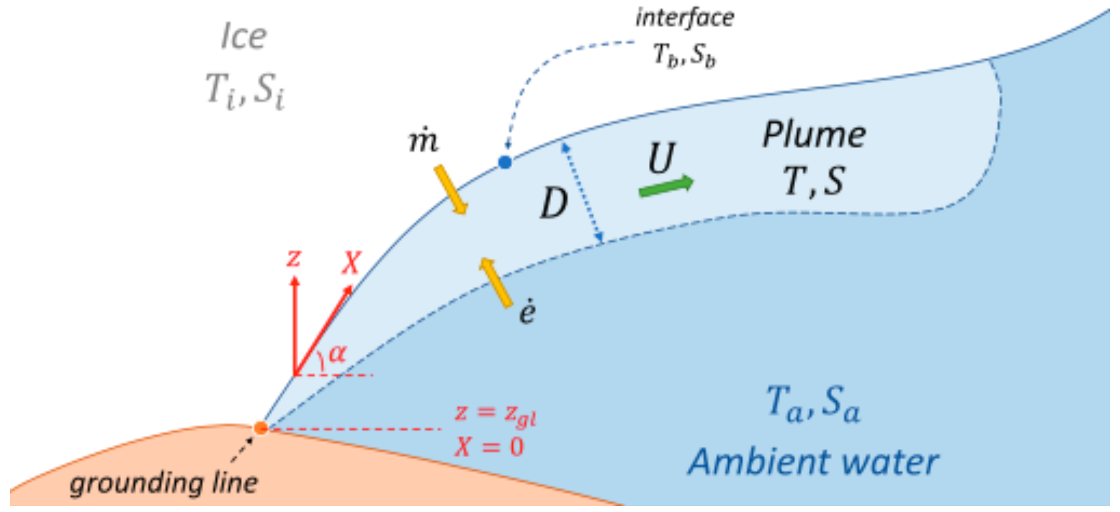
Quadratic function of thermal forcing
[De Conto & Pollard (2016), Favier et al. (2019)]





Box model
[Olbers & Hellmer (2010), Reese et al. (2018)]

Plume parameterisation
[Jenkins (1991), Lazeroms et al. (2018 & 2019)]



Lazeroms et al., 2019

Evaluation with observations:

- In-situ observations are very difficult to make and therefore sparse
- Satellites cannot observe the cavities directly and estimates are uncertain
- Possible temporal mismatch between input temperature and salinity profiles to the parameterisations and target melt rate

Evaluation with models is one solution.

Assessment in idealized coupled ocean-ice-sheet model simulation was done [Favier et al., 2019].

But:

- Only one (idealized) ice shelf
- And, when applied to several Antarctic ice shelves, empirical corrections were needed to get the right present-day melt rates underneath individual sectors or ice shelves [De Conto and Pollard 2016, Lazeroms et al., 2018, Jourdain et al., 2020]

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How we tackle the problem

Remember: Our goal is to assess and tune existing melt parameterisations **with a circum-Antarctic approach.**

"Perfect model" approach

We use a circum-Antarctic ocean simulation (resolving cavities) as a virtual reality to tune the parameters in the parameterisations => self-consistent state and all needed information available

Simulation: *NEMO global ocean simulation conducted by P. Mathiot (for TiPACCs), on eORCA0.25 grid for the time period 1958-2018*
NEMO resolves cavities and melt at the ice-ocean interface

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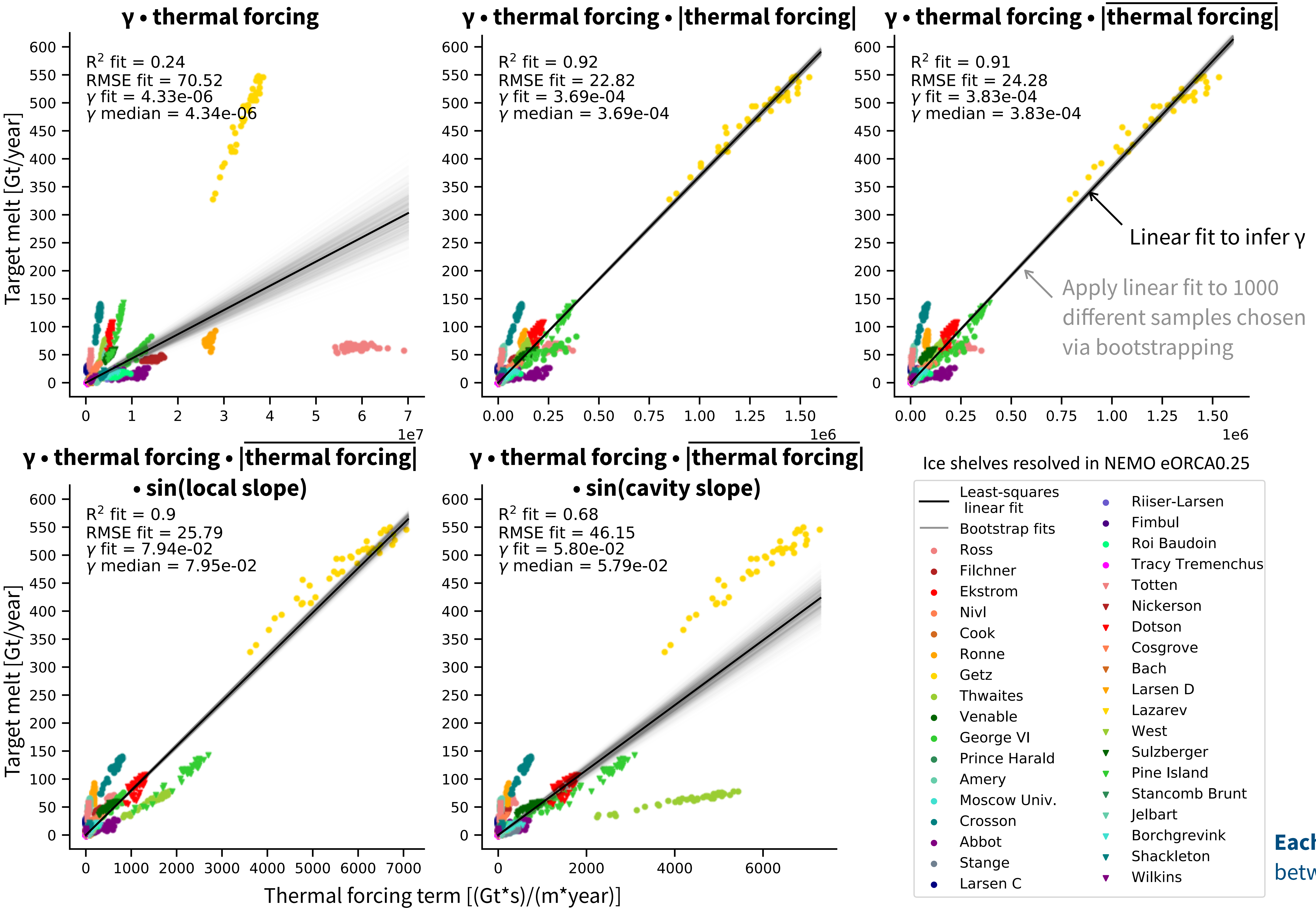
Results (1) Tuning of the "simple" parameterisations (linear and quadratic)



What's thermal forcing? 🤔
thermal forcing = T_{water} - $T_{freezing}$

What's γ?
It's the heat exchange velocity, this is what we want to tune!

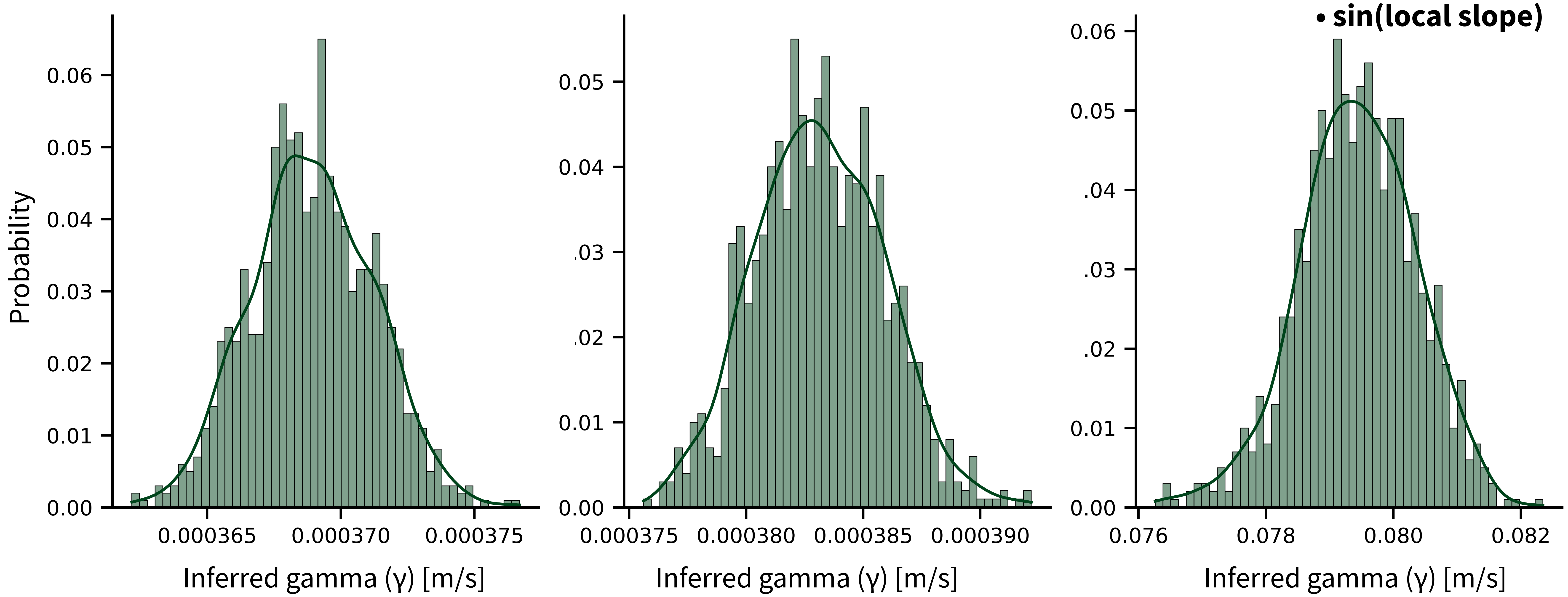
- Linear parameterisation (γ • thermal forcing) does not really fit well (highest RMSE, lowest R^2)
- Lowest spread in the inferred γ for quadratic approaches
- Order of magnitude of γ depends on parameterisations, scaling factor needed for correction! *(work in progress)*

Each point = a year between 1980 and 2018

Comparison to ISMIP

Results (2) Uncertainty of inferred γ (from bootstrapping) and comparison to ISMIP values

γ • thermal forcing • |thermal forcing| γ • thermal forcing • $|\overline{\text{thermal forcing}}|$ γ • thermal forcing • $|\overline{\text{thermal forcing}}|$ • sin(local slope)



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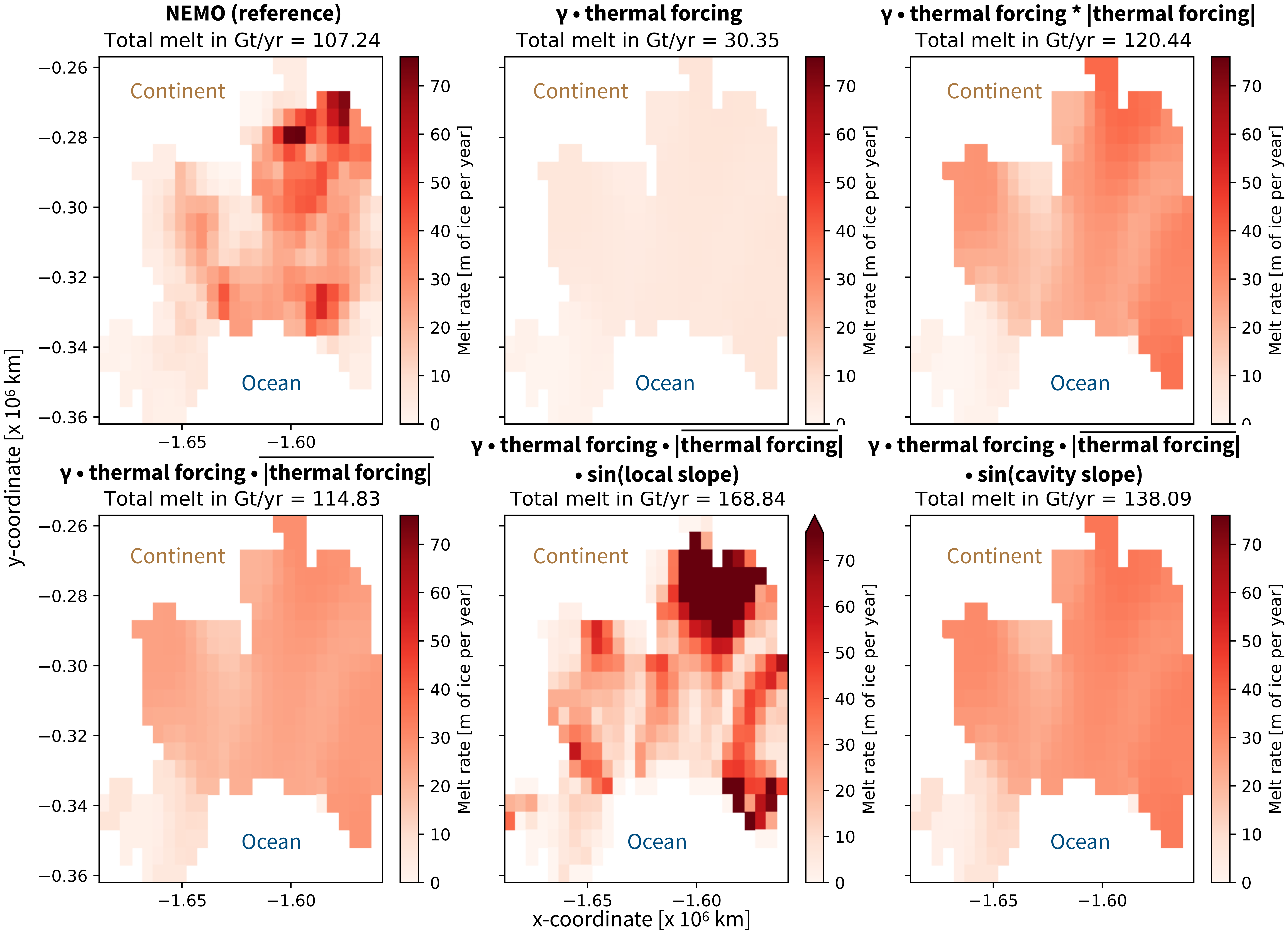
- The range of inferred γ (from 1000 bootstrap experiments) is very small compared to the difference between the ISMIP “MeanAnt” and “PIGL” recommendations

- For all cases, the inferred γ are closest to the “MeanAnt” value.
  In the 2nd formulation, the inferred γ are outside the uncertainty window of the two ISMIP recommendations.

Spatial patterns

Results (3) Application of newly tuned γ / Example of Pine Island Glacier

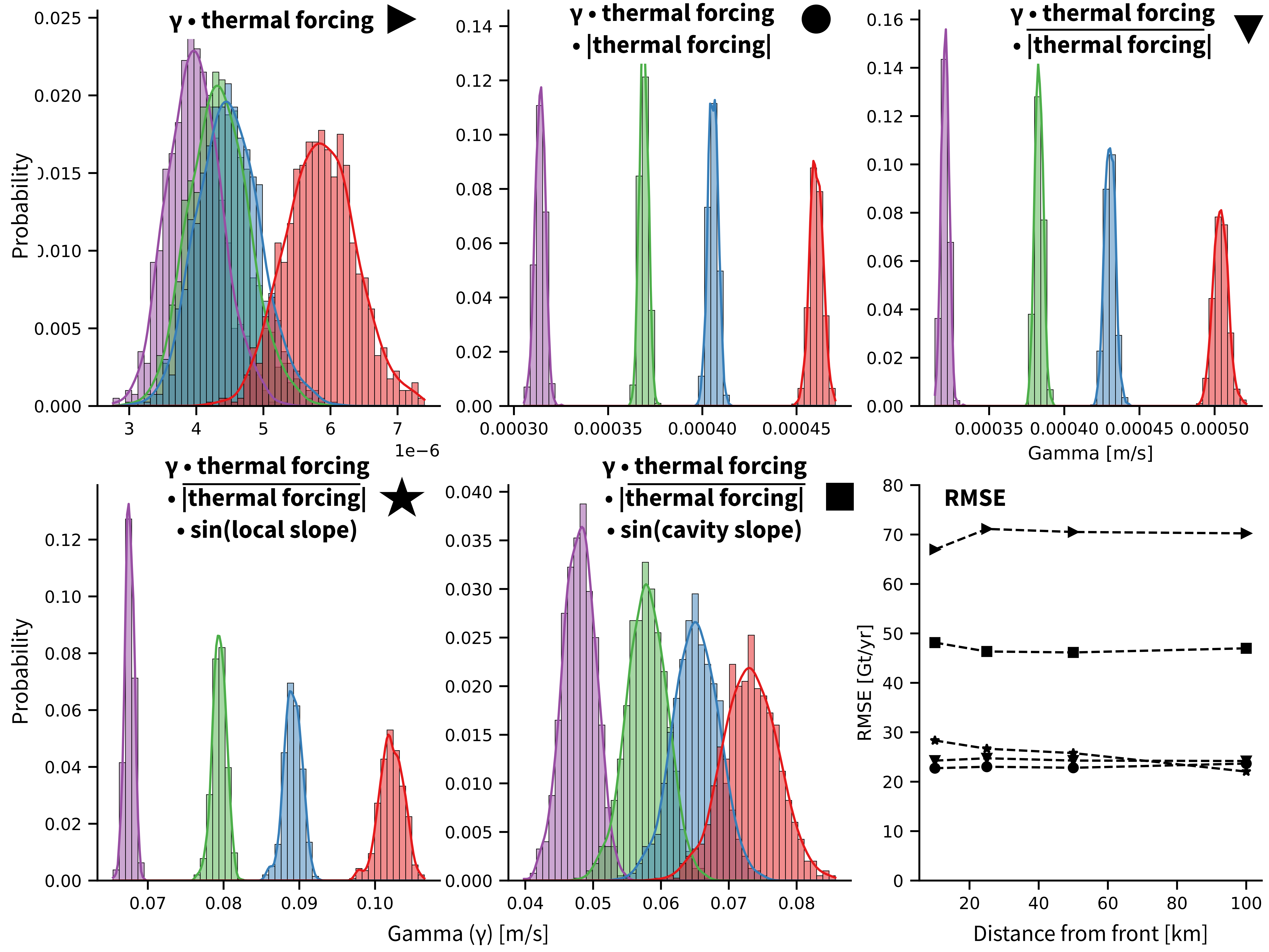


- Small spatial variability for parameterisations not including the local slope
- Including the local slope can locally lead to large overestimations
- No "perfect" solution so the choice depends on the application of the parameterisation
- Uncertainty of spatial patterns is important for application to ice sheet models *(work in progress)*

Mean melt rate over 1980 to 2018

Sensitivity of γ to input T and S

Results (4) Dependence of γ on origin of the input water properties



All previous plots were obtained by taking the mean temperature and salinity profiles within 50 km of the ice front

but

how high is the influence of the domain over which the mean is taken?

Histogram legend

Domain over which the mean oceanic temperature and salinity profiles (as input to the parameterisation):
Within 10 km, 25 km, 50 km, 100 km of the ice shelf front (continental shelf only)

- γ depends on the origin of the input water properties
- Should the choice of γ depend on the location of the input temperature and salinity? *(work in progress)*

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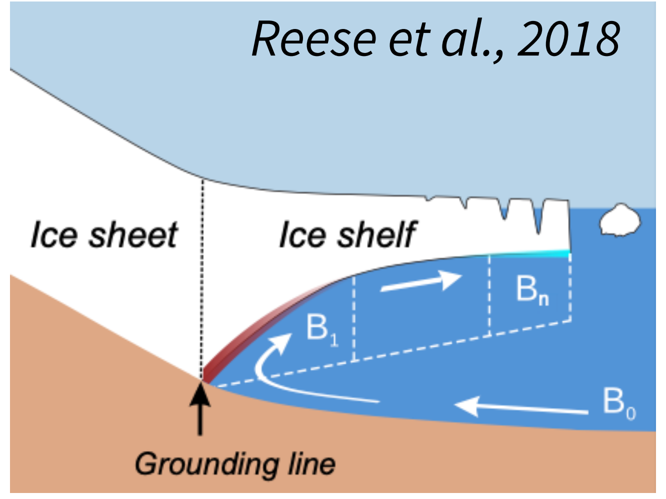
Coming soon…

Tune existing **complex** melt parameterisations **with a circum-Antarctic approach.**



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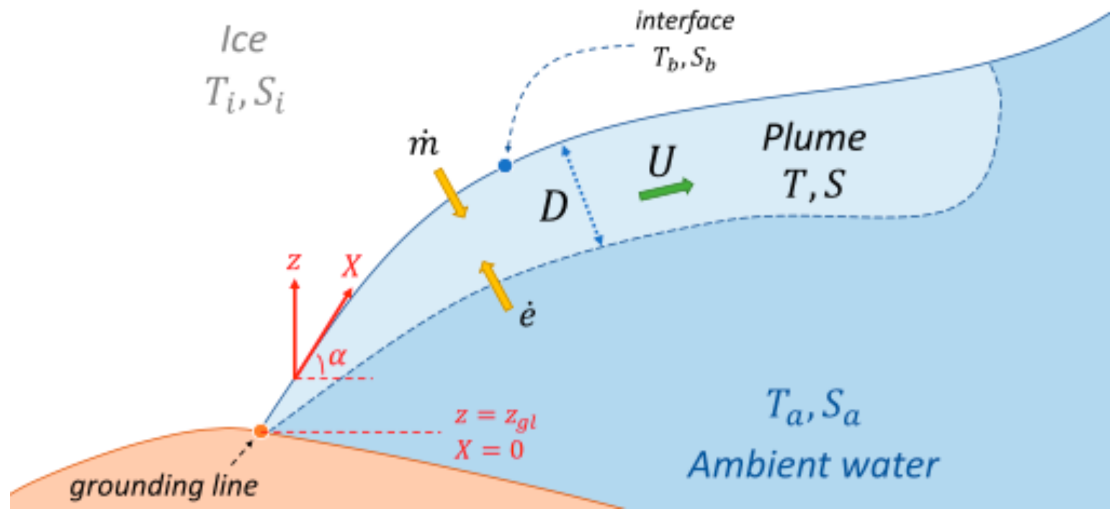

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With the same approach as the simple parameterisations but more elaborated method than a linear fit is needed

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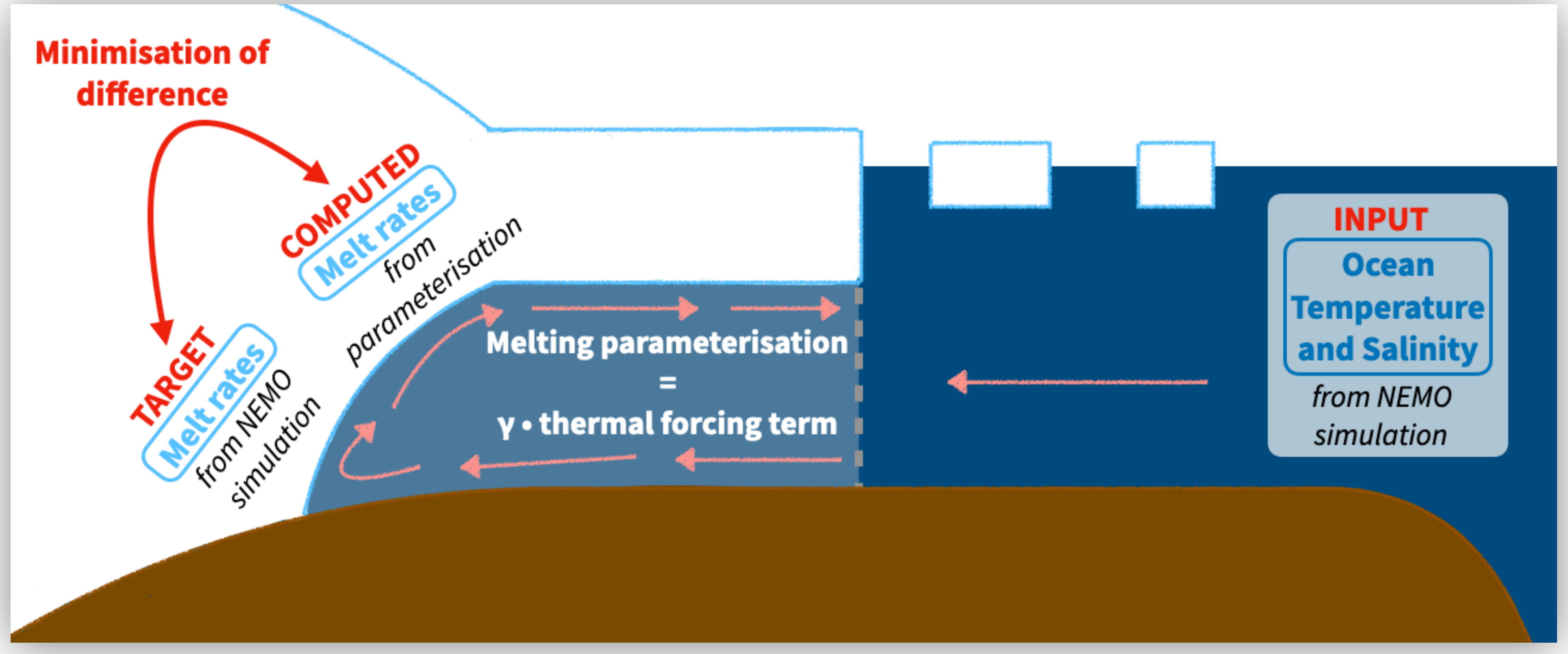

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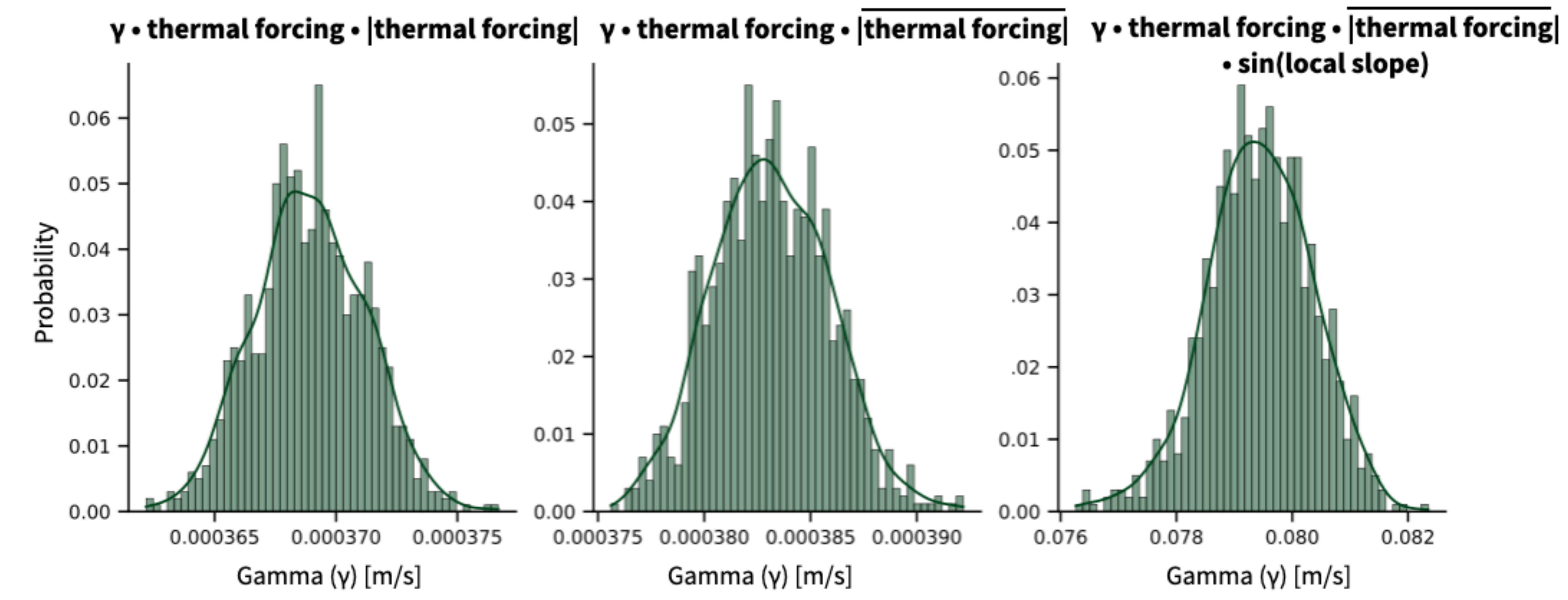

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